

The GRAVITAS Observatory

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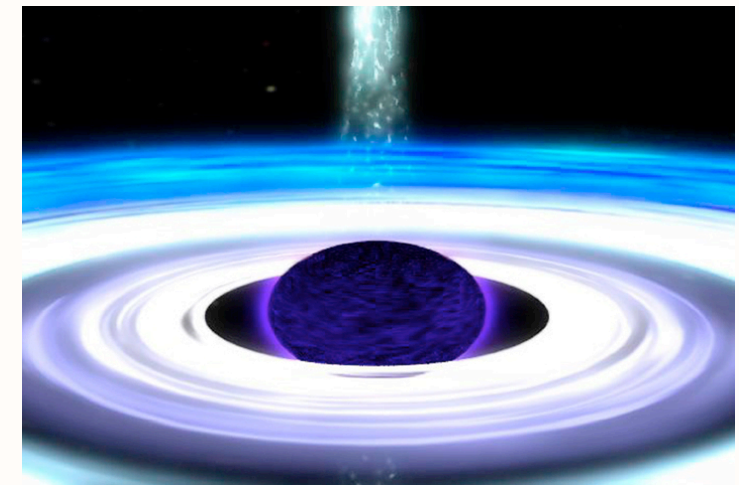
<http://gravitas.cesr.fr/>

GRAVITAS background

- GRAVITAS is a mission concept that was proposed to the M3 AO
 - ✓ Working hypothesis: For a launch in 2022, or even as earlier as 2020, if the first large mission (L1) is delayed
 - ➔ Technology developments had to be minimal (e.g. to rely mostly on European technology for the payload)
- AGNs and galactic XRBs are the main targets of GRAVITAS
 - ✓ Strong gravity and matter under extreme conditions science themes of Cosmic Vision do not require an IXO-like high angular/spectral resolution (cost driver), but do require the largest possible effective area around 6 keV
 - ➔ GRAVITAS puts emphasis on effective area rather than on angular resolution (and spectral resolution) and adds a bright source capability to cope with the extreme fluxes of X-ray binaries
 - ➔ Requires focussing optics for low and well characterized background (for AGN), to reduce detector size, hence cooling constraints,

GRAVITAS science

- Primary focus : Matter under extreme conditions
- Science items:
 - ✓ Strong gravity around black holes and neutron stars
 - ✓ Black hole spin measurements
 - ✓ Accretion physics (inflow/outflow)
 - ✓ Neutron star equation of state
 - ➔ Plus a lot of exciting observatory science (clusters, stars, ...)
- The technique: time-resolved spectroscopy of active galactic nuclei, x-ray binaries with neutron stars and black holes
 - ➔ Defines the effective area around the iron line



Main GRAVITAS performance requirements

Effective area	1.5 m ² (2.0 m²) @ 6.5 keV 0.5 m ² @ 10 keV 1 m ² @ 0.5 keV	Measure iron line parameters on sub-orbital timescales in AGNs. Constrain reflection continuum. NS atmospheres and BHB thermal disk
Energy resolution	125 eV @ 6 keV	Resolve broad iron K α profile and deconvolve from narrower features
Angular resolution (Half Power Diameter)	1' (25")	Avoid confusion for high z AGNs and clusters
Field of view	7' diameter	Background determination for faint AGNs; cluster science
Throughput	> 70% @ 150000 cps > 50% @ 1 Mcps	Cope with the brightest X-ray sources
Maximum count rate	1.5 Mcps	Observe type I X-ray bursts and X-ray novae in outbursts

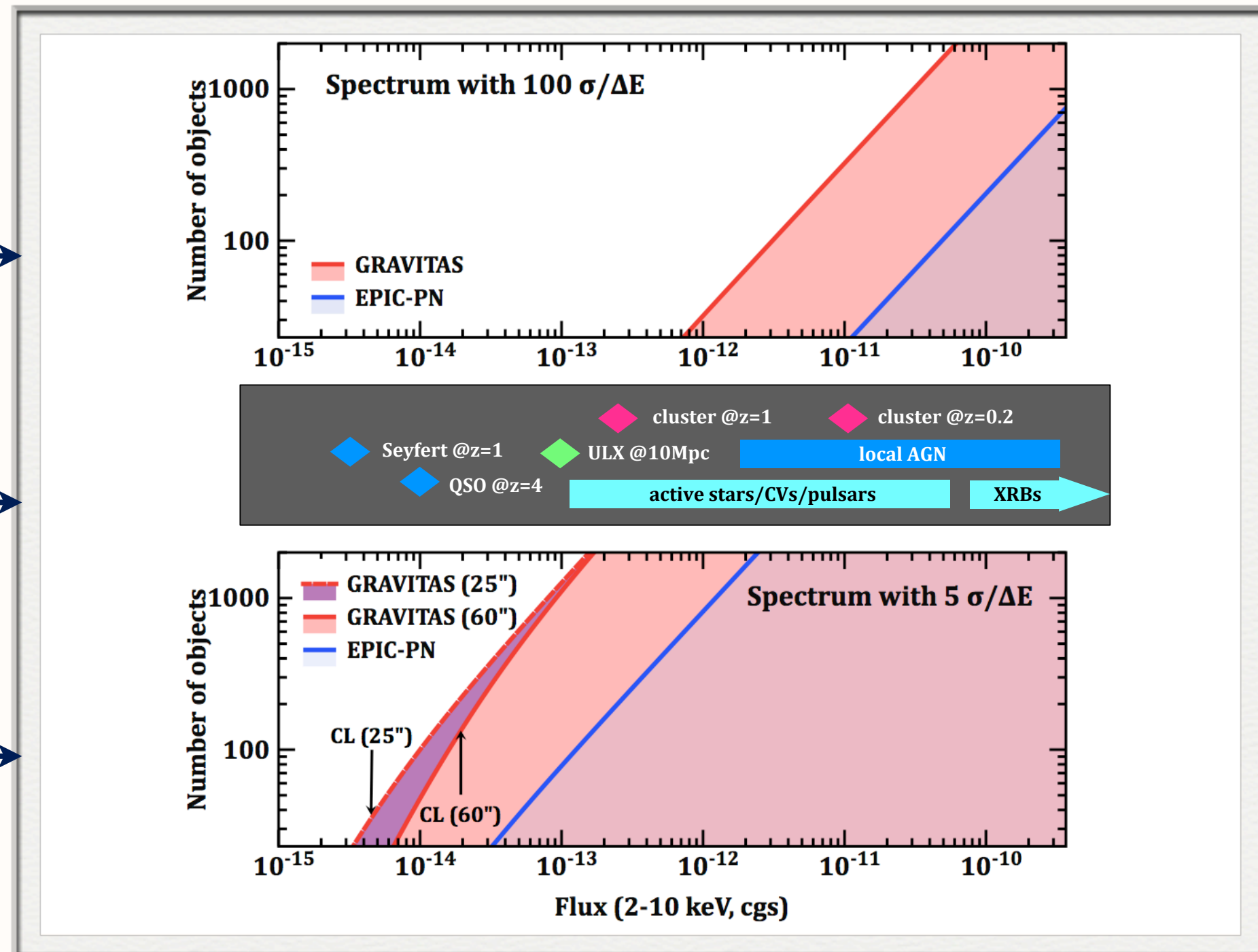
A giant leap in spectroscopic capabilities

Number of objects versus flux in 2-10 keV band

High quality spectra
(1 Mcounts)

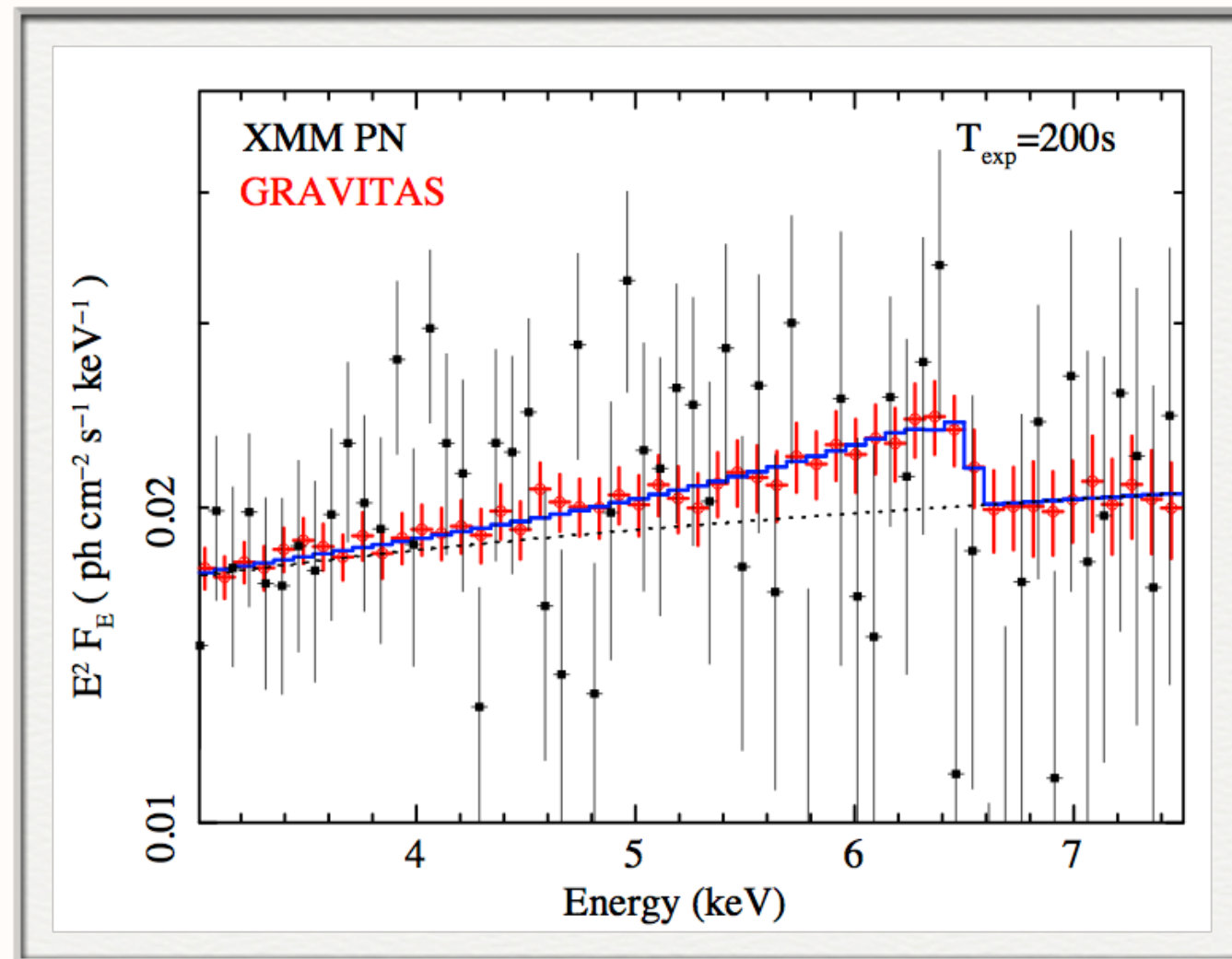
Representative
objects

Low quality spectra
(3000 counts)



GRAVITAS versus EPIC PN

- Resolving the line on the dynamical timescale at the BH event horizon: MGC 6-30-15 - available for 30-50 objects



- ✓ XMM-Newton detects iron lines in tens of AGNs - GRAVITAS could do hundreds of AGNs to get a statistically significant sample
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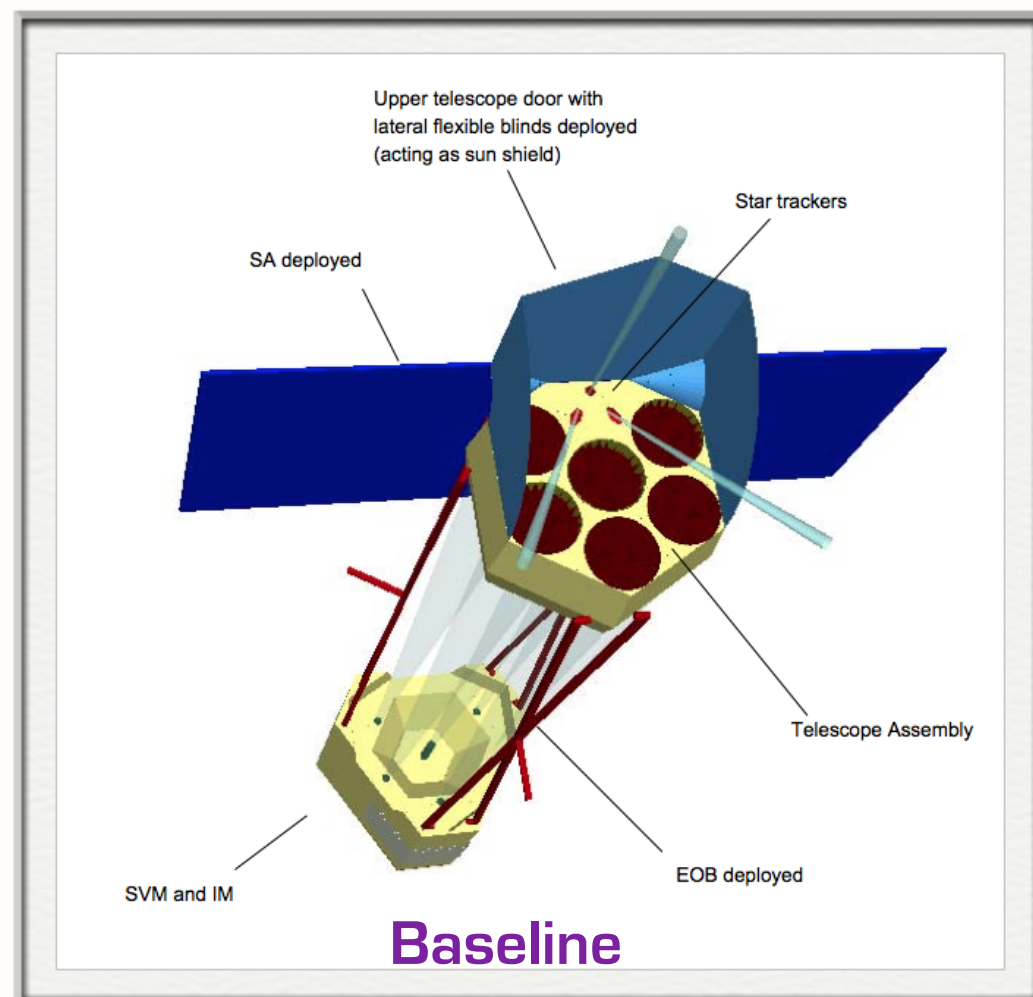
Implementation

- The GRAVITAS implementation is driven by the large effective area to be achieved at 6.5 keV, while preserving the high-count rate capabilities and some descent imaging
 - ✓ all this with the goal of keeping the design simple and robust (highest possible TRL) and within the M class envelope
 - ➔ Multi-mirror design with a focal length of 12 meters, hence requiring an extendable optical bench (would rely on NuSTAR & ASTRO-H heritage)
 - ➔ Slumped glass optics or customized IXO SPO optics - European technologies
 - ➔ 1 single type of focal plane instrument (passively cooled) - the high framerate imager (HIFI), relying on IXO-WFI/HTRS heritage
 - ➔ Low earth orbit (600 km, 0 degree inclination) constrained by the launcher cost
 - ✓ Two parallel industrial pre-studies (Astrium-D and TAS-F) performed for the proposal preparation (as well as support from CNES)

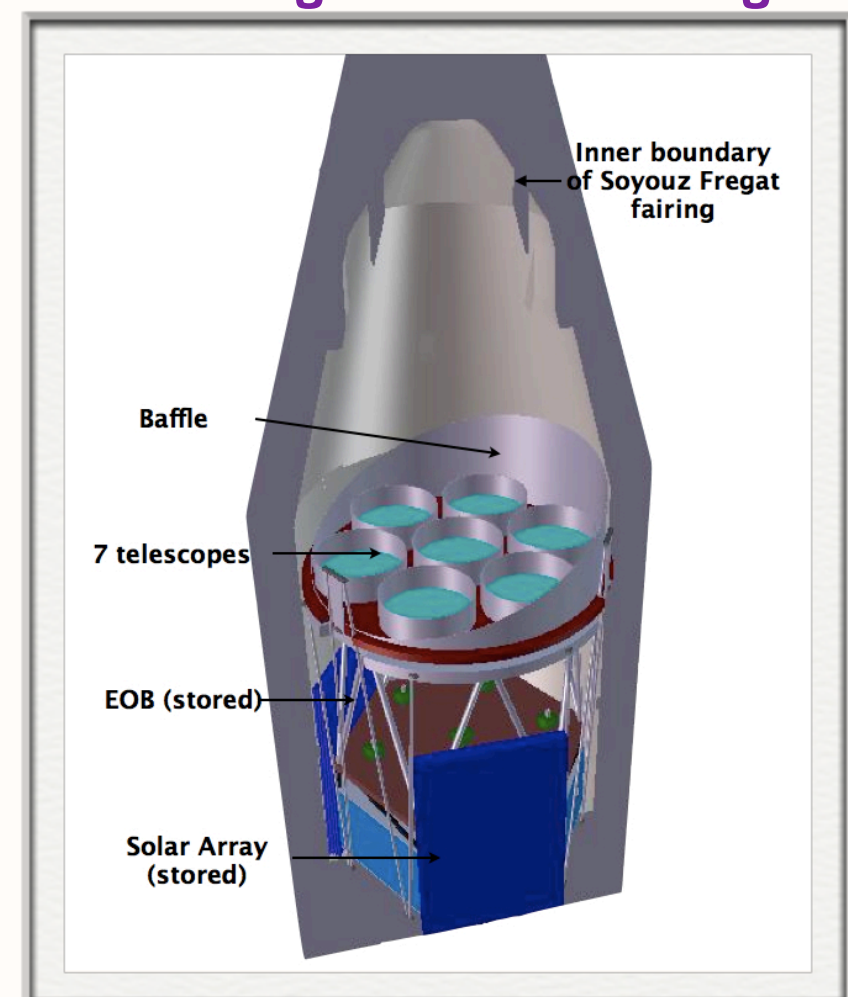
GRAVITAS design

- 2 parallel studies: similar configurations and budget resources compatible with the M boundary conditions (with reasonable assumptions for member state contributions and international partnership)

ASTRIUM-D design: deployed configuration



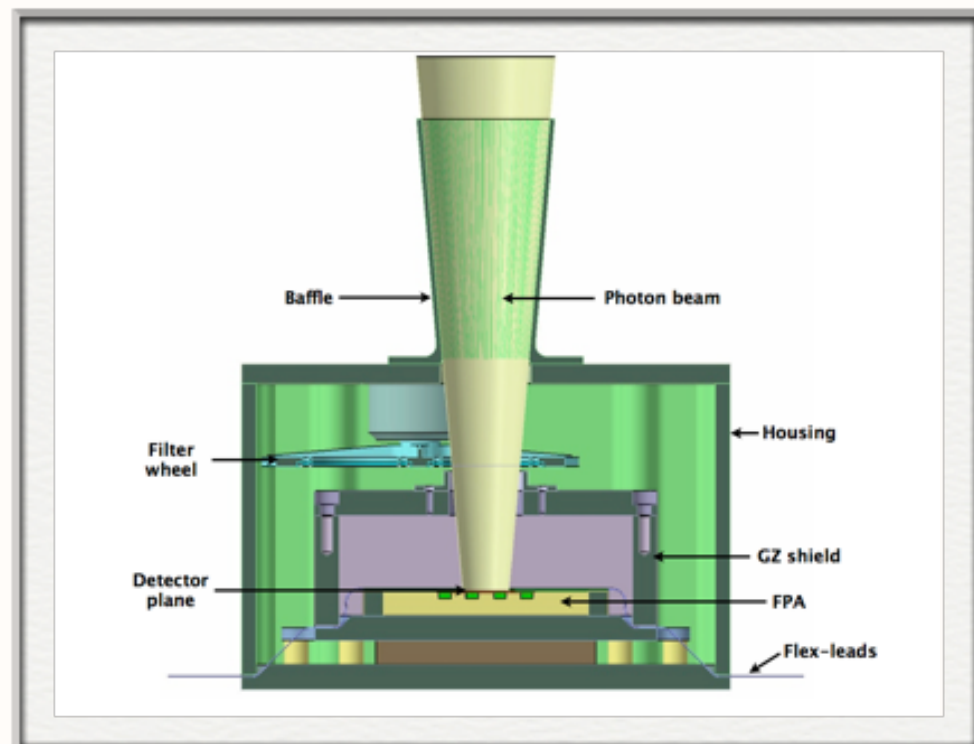
TAS-F design: stowed configuration



GRAVITAS payload

- Optics: slumped glass (à-la NuSTAR) or customized SPO (à-la IXO)
 - ➔ Both are European technologies
 - ➔ Capable of meeting the required angular resolution today, and fairly soon the goal (or even above)

Cut view of HIFI



Mirror module

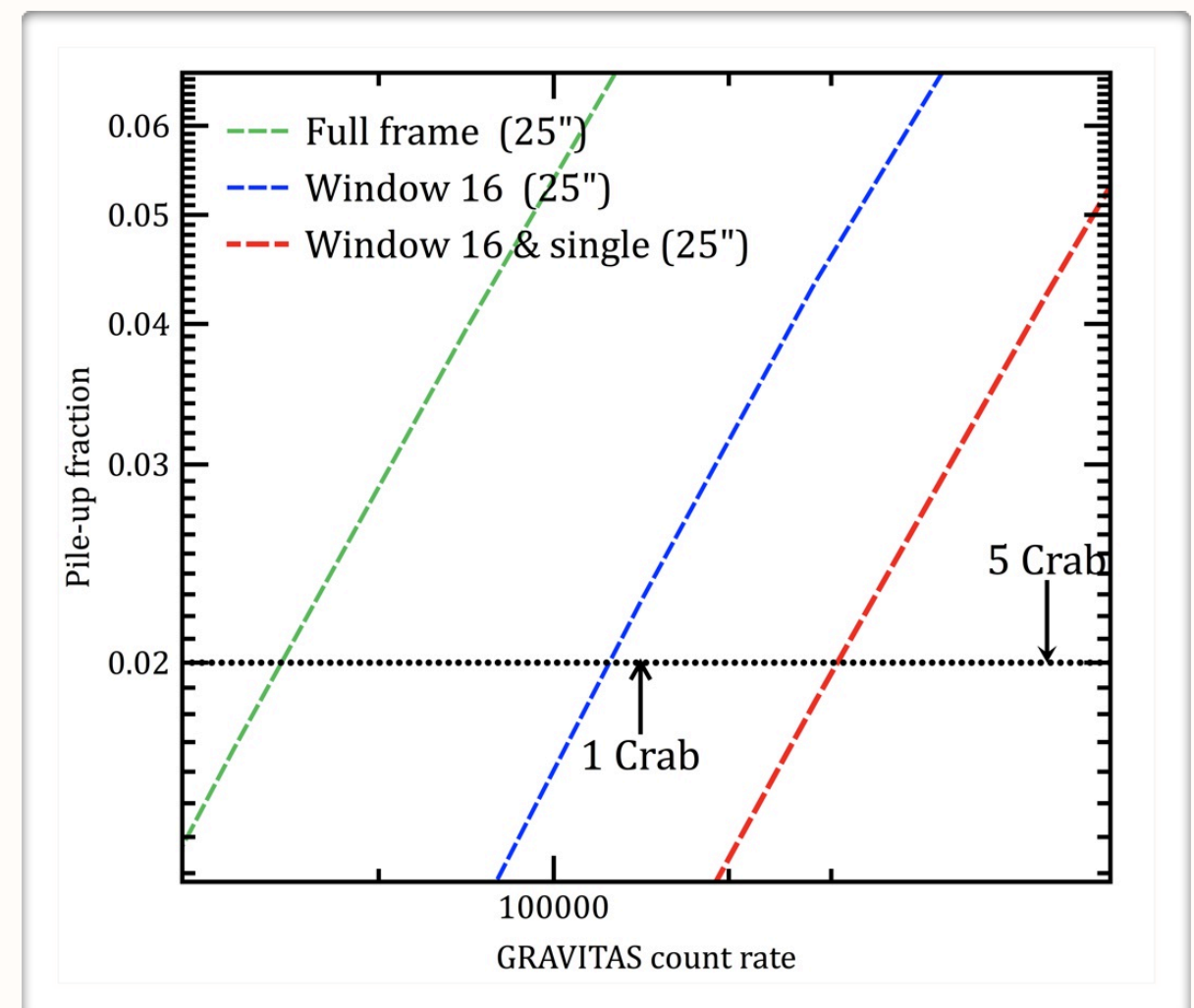


- Detector: High Framerate Imager (DEPFET array/Active Pixel sensor)
 - ✓ High quantum efficiency (0.3-15 keV), good energy resolution (125 eV @ 6 keV)
 - ✓ 64 x 64 pixels cover the 7' arcmin FOV
 - ✓ High technology readiness level

Pile-up performance of the HIFI instrument

- Estimated through end-to-end simulations - pattern recognition,..
- ✓ realistic input spectra and variability - 150000 cps (or 1 Crab, 6 telescopes)
- ➔ 0.1% pile-up in window mode (with rejection of multiple events, i.e. events depositing signal charge in more than one pixel, so called single events)

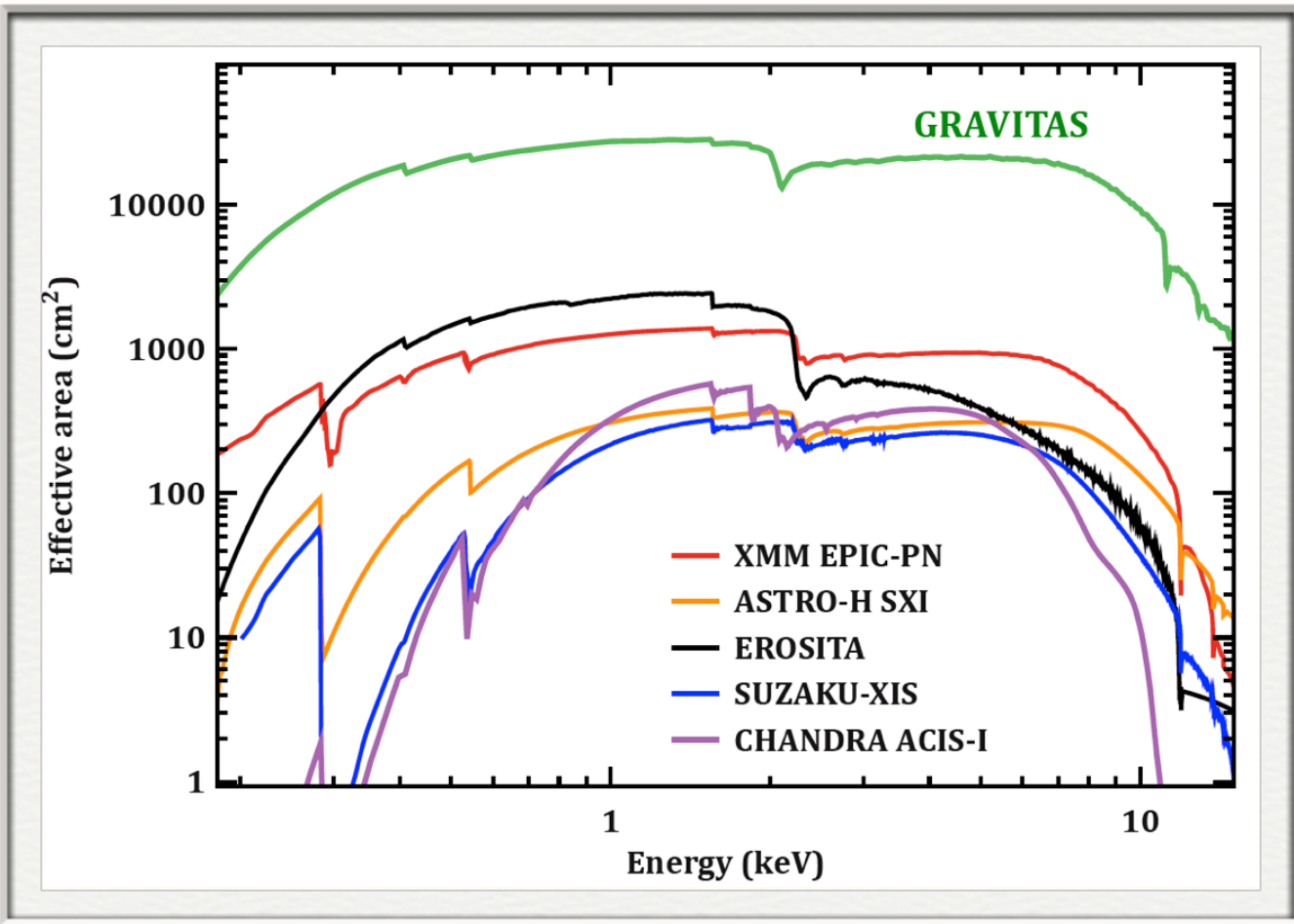
Different readout modes: the full frame mode (64 μ s) and the windowing mode (16 μ s). The windowing mode with single events only discards signals, which are shared among two or more pixels.



Observatory science

- This huge leap in effective area brings great potential for additional science

Effective area comparison



Comets and Planets	Solar-wind interactions, charge exchange physics
Stars	Mass-loss mechanisms, reverberation mapping of flares and circumstellar material
Pulsars	Particle acceleration, pulsar winds, cooling, neutron star equation of state
Supernovae & SNR	Explosion physics, chemical enrichment, particle acceleration, SNR progenitors
Galactic Centre	SgrA* monitoring, past activity from X-ray reflection
Local galaxies	XRB source populations, ultra-luminous X-ray (ULX) source studies
Starburst Galaxies	Chemical enrichment, galactic winds
Elliptical Galaxies	Dark Matter, chemical enrichment
Absorbed AGN	Energetics, census and evolution of massive BH, cosmic feedback
Clusters of Galaxies	Measurement of mass energy of Universe; Dark Matter and Dark Energy • Evolution and chemical enrichment
Gamma-ray bursts	Spectral evolution of afterglows

Conclusions

- GRAVITAS is a mission concept that was pre-selected by the ESA AWG, thanks to its well focused and strong science case, mapping closely the objectives stated in Cosmic Vision (plus great "for free" additional observatory type science)
 - ✓ It was later considered by ESA as too (big)ambitious within the constrained planning and envelope of an M class mission
- The GRAVITAS design provides large effective area around 6-7 keV and imaging/timing/spectroscopic capabilities achieved within one single instrument
 - ➡ These elements may be helpful for discussions about a rescoped IXO